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Lean Six Sigma Implementation For Improving Sewing Process in Apparel Industry

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Abstract— The garment manufacturing industries faces significant challenges to stay competitive and survive in the global market due to the highly flexible and dynamic customer demand for top-quality products at lower prices. Thus, the product quality and product cost both are very critical concerns for garment manufacturers. The variations in sewing process are not acceptable and variations are mainly responsible for defects, which leads to increasing overall production costs, lowers profits and customer dissatisfaction, among others. Therefore, due to the competition of today's business climate in textile sector, many garments manufactures are working to find the ways for improving quality of the products and reducing defects percentage to a minimum level. On one hand Lean technique can help to eliminate the production waste and convert the system into highly adaptive production system in order to meet the customers demand. On the other hand, Six Sigma intend to reduce process variability, improving quality of the product. Aiming to provide applicable improvement proposals for the sewing process in apparel industry, this research is conducted in which Lean and Six Sigma is implemented through DMAIC (Define, Measure, Analyze, Improve, and Control) approach. The methodology developed in this study has increased the sigma level from 3.9198 to 4.3546 which dropped the defect rate by 26%. Moreover, the preventive & Proactive actions proposed in this study helped to reduce the thread wastage by 30% & 36% on Lock-Stitch and Over-Lock machines, respectively and saved 1,29636 Rs. per month which can further be improved in the near future by reducing defects percentage, reducing variations in process, and improving overall quality of the product.

Keywords— DMAIC, Kaizen, Lean Six Sigma, Process Improvement

I. INTRODUCTION

Apparel industry refer to the sector of the economy involved in the production, manufacturing, and distribution of clothing and accessories. This industry encompasses a wide range of activities, from designing and sourcing materials to manufacturing, marketing, and retailing garments. It is a vital part of the global economy, with numerous companies and brands operating in various regions around the world and caters to diverse market segments, including men's, women's, and children's clothing, as well as specialized sectors such as sportswear, luxury fashion, and work wear. The garment manufacture sectors are facing several challenges such as, low productivity, high defects percentage, high rejection rate, and low profits. These challenges can be addressed by optimizing the sewing process, and reducing the defects percentage to a minimum level. One of the most significant methods to improve sewing process is Kaizen (Lean tool) implementation which focuses on continuous improvement of the process [1]. The Lean concept was originated in Japan when the manufacturing sector was not in a position to afford large investments in redesigning their industries as, this concept helps to reduce cost by reducing waste percentage to a minimum level, and increasing the rate of production [2]. The process variation which is also responsible for nonconformities of product, can be controlled using DMAIC, a Six Sigma Methodology [3]. This methodology aims at reducing the process variation to a minimum level [4], as it provides an effective methodology when combined [5]. Moreover, it also helps to address the major causes of CTQS [6]. This has also transformed from metric to methodology, and eventually into a managerial strategy [7]. The DMAIC Six sigma methodology consists of five steps [8]. In first stage, problem is defined. In second stage the performance of the current process is measured. The third stage of DMAIC methodology is used to analyze the data. The fourth stage is to improve the process, while in fifth stage the new process is controlled as summarized in Figure 1 [8]. It has been noticed that if Lean six sigma methodology is used as a management strategy it can help to provide a very competitive benefit to the companies to compete with competitors, and survive within the global market [9]. This methodology acts as a quality assurance tool, which helps them to make some bottom-line improvements [10]. Lean six sigma methodology is a tool for continuously improving quality, reducing waste, reducing process variation, and helps to optimize the overall production process [6].

This methodology has been linked with large manufacturing firms like Motorola, who firstly introduced the Six Sigma methodology. The motivation behind putting this into effect is to reduce defects and bring financial savings [11], improve quality of the process and to improve customer services [12].

The purpose of this study is, to highlight the successful deployment of Lean Six Sigma methodology by its implementation in apparel industry. Thus, we explored, with the help of literature, how Lean Six Sigma methodology helps to figure out the major defects and their causes and improve the sewing process using Kaizen which results in reduced defected percentage and improved profits.

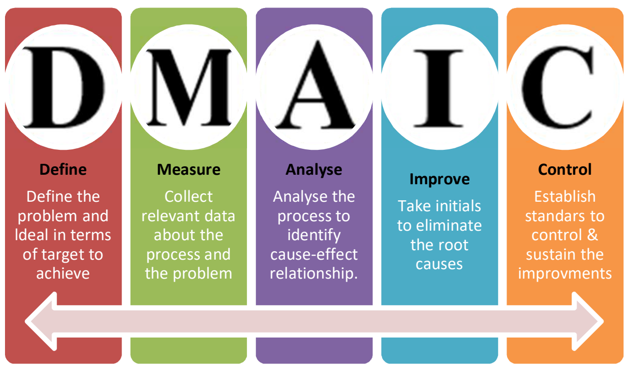

Figure 1. DMAIC Steps

II. Literature Review

In garment industries, advancements are made in the form of automating several process such as, pattern making, garment cutting, sewing, and garment finishing processes, while on the other hand, these advancements should be able to improve productivity, reduce waste, and enhance product quality. However, productivity and product quality remained low, which results in poor customer satisfaction, because it does not meet the quality requirements [13]. Thus, it is mandatory for the companies, to focus on improving, controlling, and maintaining product's quality they manufacture by developing a proper quality system [14]. One of the Six Sigma methods, which could be used in order to figure out defects and reduce them to a minimum level is DMAIC approach [15]. In manufacturing sector there are so many industries, especially textile, where this Six Sigma methodology is applied which resulted in achieving the improved, and desired quality of the product [6],[7]. The utilization of Six Sigma methodologies in the textile industries has the potential to enhance the production efficiency of textile manufacturing. Extensive research has been undertaken across different textile domain to enhance product quality and minimize defects by implementing Six Sigma approaches [8]. The percentage of major problems being faced by the garment industries could be reduced using seven Quality Tools approach in order to decrease and control defect percentage to a minimum level [18]. Similarly, in household appliance industry this methodology helped to decrease the nonconformities in aluminum assemblies which remarkably improved customer's satisfaction and save overall production cost [19]. Moreover, Six Sigma Implementation can result in improved overall performance of local shipbuilding industry and reduced defects percentage [20]. The DMAIC approach helps in exploring and optimizing internal processes, which plays a very vital role in solve the process relevant problems in mold industry [21]. There is a five-phase cycle in DMAIC approach which helps in quality improvement and is increasing popular for dealing with quality related problems that is why often called and implemented with Six Sigma [22]. On the other hand, it also helps in reducing operational cost, and is practical for continuously improving quality as well as production processes [23]. This methodology is termed as Lean Six-Sigma methodology which keeps the manufacturing process close to the target by minimizing process variation, resulting improved product quality, using X-bar Control chart tool [24]. The terminology used for continuous improvement is kaizen can be recommended in improvement stage of DMAIC which is a set of action, used in order to implement such plans which results in quality improvement and six sigma approach in parallel after figuring out the main causes responsible for product defect which is more prevalent [25]. This term denotes an ongoing process aimed at enhancing the conventional method of operation [26] which cover many techniques including Kanban, Total Productive Maintenance (TPM), Zero defects, Automation, Just-in-time (JIT), Suggestion system & Productivity Improvement [27]. However, implementing lean and Six Sigma mythologies, separately often fail to fulfill the organization's desire of achieving sudden improvement. Therefore, integrating lean and Six Sigma is mandatory for improving productivity and sustaining continuous improvement in manufacturing systems [28], [29].

Therefore, in this research lean manufacturing and Six Sigma is implemented simultaneously, in Henley production line of an apparel industry in order to decrease the quality problems by optimizing sewing process and reducing the defects percentage to a minimum level. Thus, the Lean Six Sigma is used to optimize the sewing process by continuously improving it, and to detect and reduce the defects percentage to a minimum level.

III. Contribution

To the best of my knowledge, this research aimed to implement Kaizen in improvement stage by thread cutters installation in Lock-stich and Over-Lock machine. In addition, this research contributed to estimate the cost saved and thread wastage reduction after DMAIC implementation and taking the proposed preventive and corrective actions in improvement stage, which is the novelty of this rearch.

IV. Research Method

In research methodology, the garments manufacturing process, thread consumption in sewing process, CTQ's (Critical to quality factors), defects percentage, thread wastage, increment in overall production cost due to thread wastage, and rejection of products due owing to thread wastage will be studied thoroughly and analyzed using Lean Six Sigma. Moreover, literature is further reviewed for improving sewing process and reducing thread wastage in apparel industry.

In this research, primary & secondary data sets were required, which were collected by analyzing causes of defects & sample making by direct observation as well as during panel discussion and documented production report along production defects on daily basis for 4 months.

A systematic procedure is followed in order to make this research attentive & directed. The methodology consists of four stages as shown in Figure

In **Stage 1**, the problems in apparel industry is explored, and research objectives are set. Moreover, further literature review will be conducted on Lean and Six Sigma methodologies which aims to enhance the theory implemented as problem solving technique.

In **Stage 2,** the production data and production defects for 4 months were collected. Thus, the inspection is done on weekly basis, and defect percentage is determined on end-line of production line, on weekly basis for 4 months. Once the percentage of defects is determined, the defect with largest percentage was focused, which is uncut thread. After data collection, the DMAIC approach of Six Sigma is applied; initially the defects which significantly affect the sewing process and are responsible for rejection are defined, and presented with the help of Pareto diagram as shown in figure 4 using Minitab software. Secondly, the sigma level is measured using production data and production defects with the help of following formulas [30];

$$DPU = \frac{Amount\ Defect}{Amount\ unit} \quad (1)$$

$$DPO = \frac{DPU}{CTQ} \quad (2)$$

$$DPMO = DPO \times 1{,}000{,}000 \quad (3)$$

$$Sigma\ Levels = NORMSINV\ \frac{(1{,}000{,}000 - DPMO)}{1{,}000{,}000} + 1.5 \quad (4)$$

After, measuring sigma levels, the control charts are used to analyze the nonconformities in the units produced. During this phase Why-Why analysis is conducted and control chart (P-Chart) is used to measure the statistics of nonconformities produced in the unit and to figure out the causes of these defects. Following formulas [21] are be used to find $CL\ or\ \bar{P}$ (Control-Limit), UPL (Upper Control-Limit), and LCL (Lower Control-Limit).

$$\text{CL or } \bar{P} = \frac{\sum Defects}{\sum Inspections} \quad (5)$$

$$\text{UCL} = \bar{P} + 3\left(\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}}\right) \quad (6)$$

$$\text{LCL} = \bar{P} - 3\left(\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}}\right) \quad (7)$$

Moreover, the Root Cause Analysis (RCA) is also done to analyze the main causes of the problem and their consequences. Thus, the obtained data is used to form Fishbone diagram with the help of Minitab Software. Similarly, the current thread consumption, thread wastage, defects causes due to thread wastage, and the associated costs are also be determined.

In **Stage 3**, improvements are done by implementing one of the lean tools name KAIZEN along Focused Group Discussion (FDG) using 5W+1H method. Furthermore, last phase of DMAIC is control phase, in which proper monitoring and inspection is done related to the defects, and further preventive & corrective actions are taken.

In **Stage 4**, which is the final stage of research, the sigma levels, percentage defects, thread wastage proportion and overall cost are compared before and after improvements.

Figure 2. Uncut thread defect.

V. Results & Discussion

A. DMAIC Stages analysis

Define Stage

The inspection helps to determine the Critical to Quality (CTQs) factors that usually appear, are found so accurate because in apparel industry these defects differs substantially in the types of defects. The total number of defects appeared within four months is 3660 out of 31200 inspected pieces. Moreover, weekly production report for four months along inspection and defects percentage is shown in Table 2.
The following step is to further classify the defects into types of defects which are very common in apparel industry and are

known as Critical to Quality (CTQS). Here, 15 most common CTQs are elaborated in the Table 3.

The most prevailing type of defects is the uncut thread in garment because this defect will be easily seen by the Quality Control Inspector during the visual inspection of finished products on finishing line as shown in Figure 2 and Figire 8.

The defect type along its proportion is presented in Pareto diagram of finishing section .Here, the uncut thread defect type is found the highest defect of production line in with a proportion of 24.45%.

Measure Stage

In this stage, the data of 4 months from November 2022 to February 2023 are used and initially the Sigma Level is calculated before any improvement is made as shown in Table 1

$$DPU = \frac{254}{2000} = 0.127$$

$$DPO = \frac{\mathbf{0.127}}{\mathbf{15}} = 0.008467$$

$$DPMO = 0.008467 \times 1{,}000{,}000 = 8467$$

$$Sigma\ Levels = NORMSINV\ \frac{(1{,}000{,}000-8467)}{1{,}000{,}000} + 1.5$$

$=3.888152$

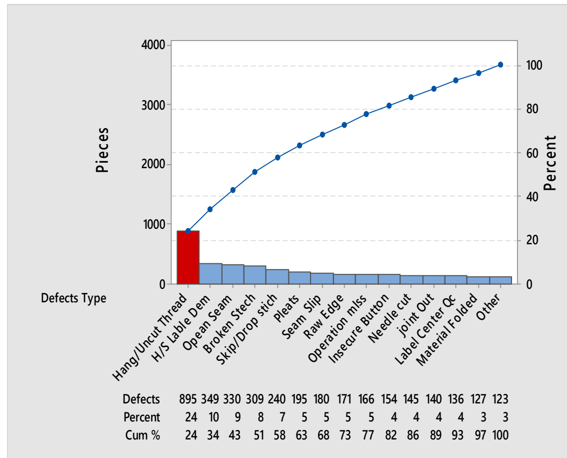

Figure 3. Pareto diagram before improvement

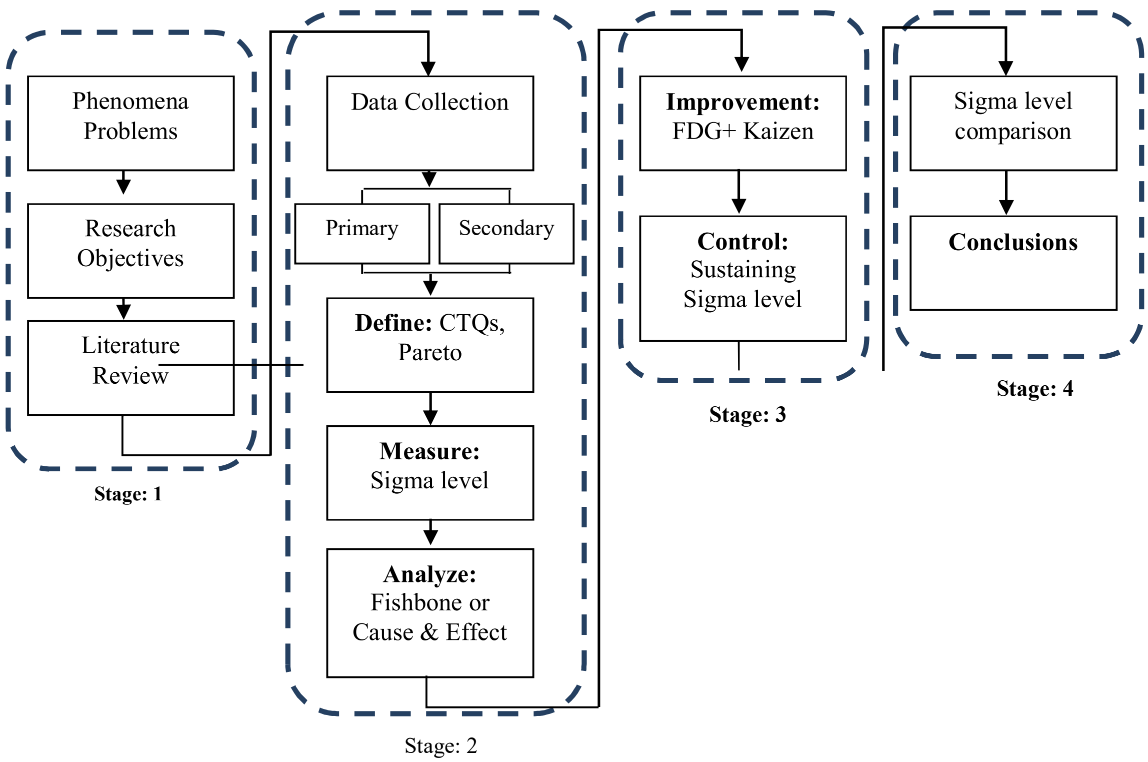

Figure 3. Research framework.

Thus, this sigma level for each week is calculated with the help of (1), (2), (3), and (4).

Analysis

The sigma level calculated in Measure stage is presented with the help of P-Chart (Control Chart) in for significant analysis, before improvement. Here, (5), (6), and (7) is used to find Control-Limit (CL), Upper Control-Limit (UCL), and Lower Control-Limit (LCL) respectively.

CL or $\bar{P} = \frac{\sum Defects}{\sum Inspections}$

$= \frac{3660}{31200}$

CL = 0.11731

$UCL = \bar{P} + 3\left(\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}}\right)$

UCL = $0.11731 + 3\left(\sqrt{\frac{0.11731\,(1-0.11731)}{16}}\right)$

UCL = 0.14006

$LCL = \bar{P} - 3\left(\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}}\right)$

$= 0.11731 - 3\left(\sqrt{\frac{0.11731\,(1-0.11731)}{16}}\right)$

LCL = 0.09455

The Figure 5 clearly illustrates that, 5 samples are located outside the control limits (UCL= 0.14006 and LCL=0.09455), which shows that the defects are out of control. Therefore, it is necessary to analyse the root cause of these defects. In order to analyse the root cause of uncut thread defect, Root-Cause Diagram (also known as Fish-Bone Diagram) is used to identify the major causes of defects occurs at finishing line. Hence, there are four main factors such that, Man, Machine, Method, and Environment shown in Figure 7 , which may be responsible for cause of defect.

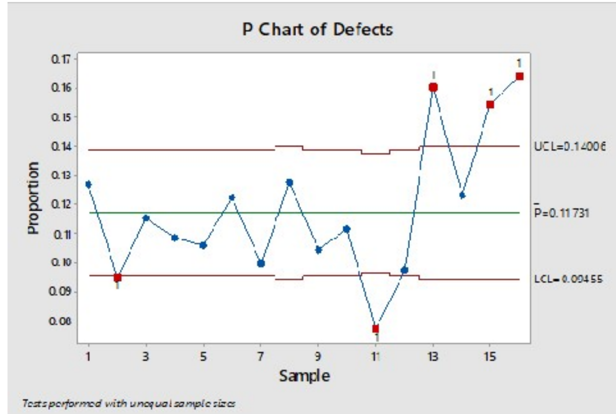

Figure 5. Control chart before improvement

Improvement

Once we determine the causes of uncut thread defect, a panel discussion, of 5 experts, was held using 5W+1H method to take corrective actions. The detailed profile of 5 experts is presented in Table 1. Moreover, the results originated using Root Cause Analysis (RCA) with the help of why-why analysis during Focused Group Discussion (FGD) with required corrective and preventive actions are briefly explained as shown in

Figure 6. Current method of thread cutting

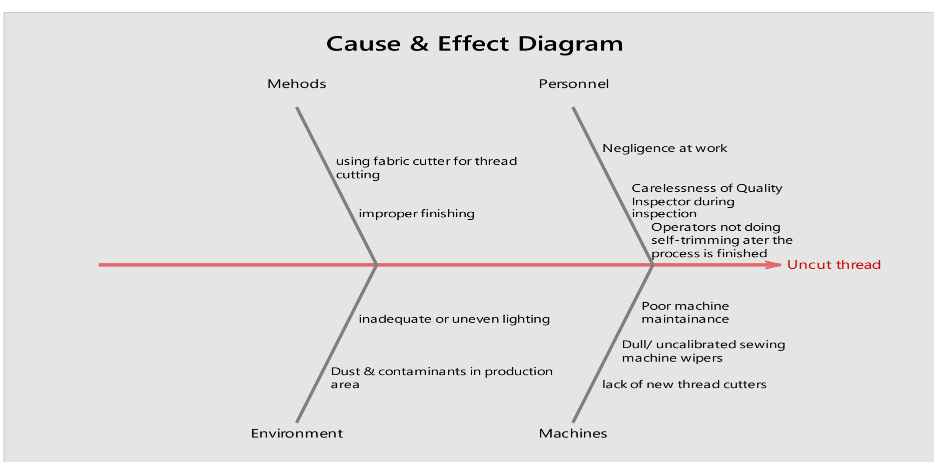

Figure 7. Fishbone diagram of uncut thread defect

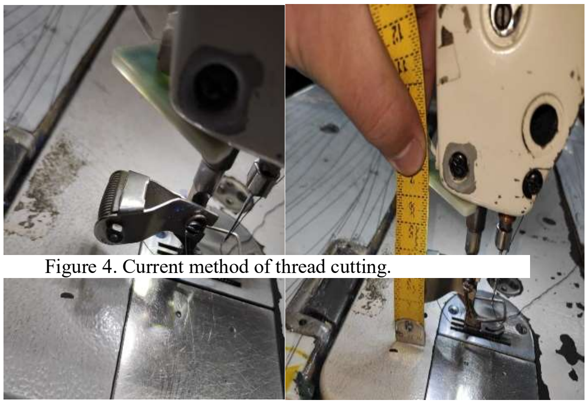

Figure 4. Current method of thread cutting.

Figure 10. Thread cutters installed on Lock-Stick machine

B. Cost saving Analysis

Previously, there were limited thread cutters due to which fabric cutters were used for thread cutting which resulted in uncut thread defect as shown in Figure 6. Moreover, the workers were not properly trained and educated about the usage of built-in cutters in machine. That's why some preventive and proactive actions elaborated in Table 4 were taken in order to control this defect.

There were two shifts, each shift consist of 12 hours. This cost benefit analysis is performed on Lock stich and Over-lock Machines

Number of machine in Division 1, 2, & 3 are;
SNLS (Lock-Stich) = 608+128 = 736
4TOL (Over-Lock) = 334+77 = 411
FL = 120+21 = 141
KANSAI = 24+6 = 30
First, we calculate the thread wastage of Lock-Stich machine;
Thread wastage per operation ≅ 10cm
Total number of Lock-Stich machine = 736
Average number of operations per machine ≅ 1000
Average thread wastage = 10×736×1000 = 7360000 cm/day
Number of cones wasted ≅ 30 cones per day
Similarly, thread wastage of Over-Lock machine;
Thread wastage per operation ≅ 11cm
Total number of Over-Lock machine = 411
Average number of operations per machine ≅ 1000
Average thread wastage = 11×411×1000 = 4521000 cm/day
Number of cones wasted ≅ 10 cones per day

From the above data, it is shown that around 40 cones are wasted per day, which in turn causes several defects including uncut thread defect. Therefore, in improvement phase some modern thread cutters were installed shown in Figure 10 & Figure 9 and workers were also trained about their usage which improved thread cutting process which on one hand reduced thread wastage while, on the other hand saved cost as calculated below;

After thread installation and training;
Thread wastage of Lock-Stich machine per operation ≅ 3cm
Total number of Lock-Stich machine = 736
Average number of operations per machine ≅ 1000
Average thread wastage = 3×736×1000 = 2208000 cm/day
Number of cones wasted ≅ 9 cones per day
Similarly, for Over-Lock machine;
Thread wastage of Over-Lock machine per operation ≅ 4cm
Total number of Lock-Stich machine = 411
Average number of operations per machine ≅ 1000
Average thread wastage = 4×411×1000 = 1644000 cm/day
Number of cones wasted ≅ 3 cones per day
Now, the savings we calculate after installation of modern thread cutters and training are;
For Lock-Stich machine;
Price per cone = 196
Number of cones saved = 21
Total savings per day = 196×21 = 4116
Total savings per month = 4116×26 = 107016 Rs.
For Over-Lock machine;
Price per cone = 145
Number of cones saved = 6
Total savings per day = 145×6 = 870
Total savings per month = 870×26 = 22620 Rs.

Figure 8. Uncut thread defect caused by Over-Lock Machine

Figure 9. Thread cutter installed on Over-Lock machine.

Table 1. Sigma level before improvement

Month	Week	Inspection	Defects	DPU	DPO	DPMO	Sigma Level	Defects%
November	1st	2000	254	0.127	0.008467	8467	3.888152	12.70
	2nd	2000	190	0.095	0.006333	6333	3.993006	9.50
	3rd	2000	231	0.1155	0.0077	7700	3.922833	11.55
	4th	2000	217	0.1085	0.007233	7233	3.945462	10.85
December	1st	2000	212	0.106	0.007067	7067	3.953857	10.60
	2nd	2000	245	0.1225	0.008167	8167	3.901381	12.25
	3rd	2000	199	0.0995	0.006633	6633	3.976529	9.95
	4th	1800	230	0.127778	0.008519	8519	3.885907	12.78
January	1st	2000	209	0.1045	0.006967	6967	3.958978	10.45
	2nd	2000	223	0.1115	0.007433	7433	3.935611	11.15
	3rd	2200	170	0.077273	0.005152	5152	4.06549	7.73
	4th	2000	195	0.0975	0.0065	6500	3.983769	9.75
February	1st	1800	289	0.160556	0.010704	10704	3.800721	16.06
	2nd	1800	222	0.123333	0.008222	8222	3.898899	12.33
	3rd	1800	278	0.154444	0.010296	10296	3.815372	15.44
	4th	1800	296	0.164444	0.010963	10963	3.791649	16.44

Table 2. Sigma level before Inprovment

Month	Week	Inspection	Defects	DPU	DPO	DPMO	Sigma Level	Defects%
April	1st	2000	73	0.0365	0.002433	2433	4.315729	3.65
	2nd	2000	56	0.028	0.001867	1867	4.399857	2.80
	3rd	2000	61	0.0305	0.002033	2033	4.372944	3.05
	4th	2000	69	0.0345	0.0023	2300	4.333787	3.45
May	1st	2000	70	0.035	0.002333	2333	4.329185	3.50
	2nd	2000	58	0.029	0.001933	1933	4.388839	2.90
	3rd	2000	71	0.0355	0.002367	2367	4.324643	3.55
	4th	1800	54	0.03	0.002	2000	4.378162	3.00
June	1st	2000	69	0.0345	0.0023	2300	4.333787	3.45
	2nd	2000	66	0.033	0.0022	2200	4.347963	3.30
	3rd	2200	70	0.031818	0.002121	2121	4.35955	3.18
	4th	2000	67	0.0335	0.002233	2233	4.343174	3.35
July	1st	1800	55	0.030556	0.002037	2037	4.372369	3.06
	2nd	1800	59	0.032778	0.002185	2185	4.350113	3.28
	3rd	1800	53	0.029444	0.001963	1963	4.384053	2.94
	4th	1800	61	0.033889	0.002259	2259	4.339494	3.39

Table 3. Critical to Quality factors

Defect type	Amount
Hang/Uncut Thread	895
Broken Stich	309
H/S Label Dem	349
Open Seam	330
Skip/Drop stich	240
Pleats	195
Seam Slip	180
Raw Edge	171
Insecure Button	154
Operation miss	166
Needle cut	145
joint Out	140
Label Center Qc	136
Material Folded	127
Button Alignment	123
Total	3660

Control

The result of improvements can be seen by the increment in sigma level. The table shows an abrupt decline in the number of defects which enhanced the sigma level as shown in Table 2 . Similarly, the control chart in Figure 11 depicts that all the inspected products are within the control limits, which gives the information that defects are managed after making required improvements in process as well as training people

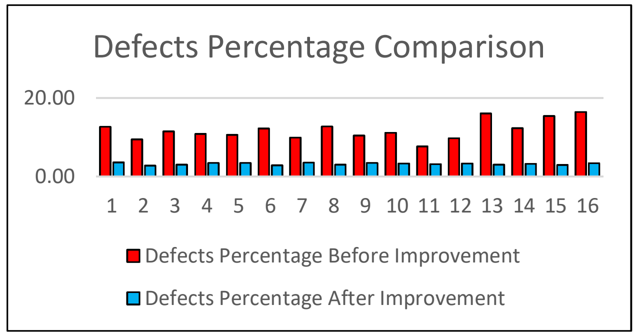

Figure 6. Defect percentage comparison

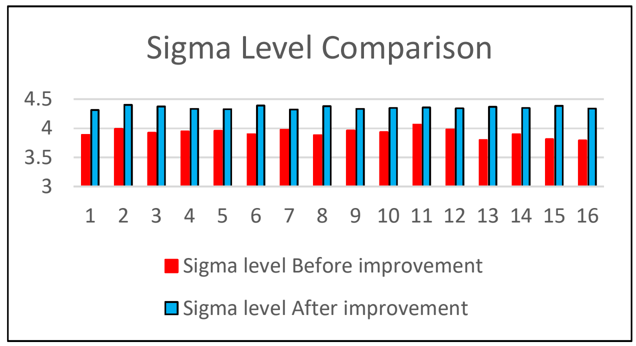

Figure 7. Sigma level comparison

Table 4. FW+1H result

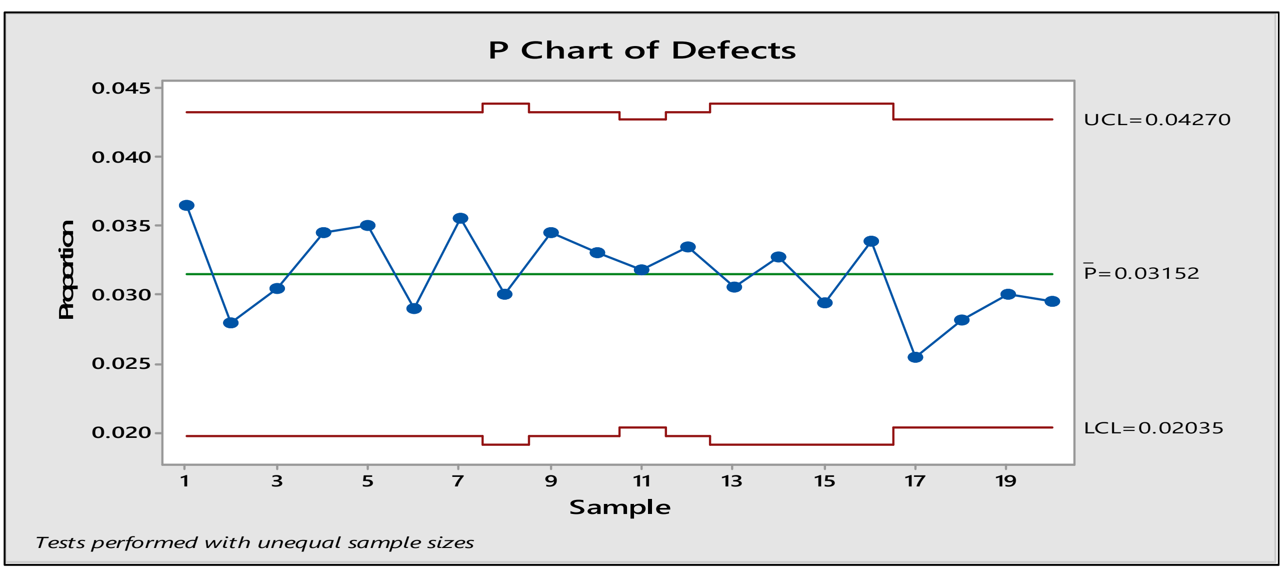

Figure 5. Control chart after improvement.

Sr. No	What	Why	How	Who	When	Where
	What is the problem?	Why it should be dealt with?	How to deal with it?	Who is in charge?	When will it be implemented?	Where is it carried out?
1	Fabric cutters are used for thread cutting	The main reason of controlling thread wastage is to reduce thread consumption. As a result it will reduce cost. It is important because it takes a lot of money and resources to make yarn, if we reduce thread wastage our money and resources will be saved which in turn will have a good impact on environment.	By installing auto cutters in machine which cuts the thread whenever the operation is completed, in this way wastage will be reduced and our thread consumption will be minimized. Currently thread wastage is 25% and that should not be more than 10%. By using pneumatic cutters on machine the thread wastage can be controlled at higher accuracy.	Machine shop & Floor Mechanic	28/3/2023	Thread usage occurs mainly in sewing area. So sewing area should be the focus point as there is maximum wastage of thread.
2	Improper finishing	It leads to products return. Which require rework, results in high overall production cost & customer dissatisfaction	Training and educating workers about techniques, procedures, and standards. Quality checks & inspections should be implemented to rectify these issues before forwarding them ahead.	IE Dept.	2/3/2023	Finishing line
3	Workers negligence at work	It results in errors in production process, which effect the product quality. Thus waste resources and increase overall cost	Defining the behaviours or actions which are considered negligent. Using warning signs, educating workers. Implementing strict supervision, regularly to correct them. Moreover, reward & appreciate workers for showing positive behaviour during work	Production Dept.	2/3/2023	Meeting room
4	Carelessness of Quality Inspector during inspection	It may results in reaching defective products to customer which may lead to customer dissatisfaction, returns, increased rework, & financial losses.	Observe & document the careless behaviour of inspector and record the incidents and its impact on inspection. Inspectors should be met in personal & discuss the issues after listening to their perspectives.	Quality control Dept.	8/3/2023	Meeting room

5	Self-trimming was not done by the workers	It results in major quality defects, such as uncut thread, uneven seams which effect overall product quality	Investigate the main reason for their resistance. Provide them proper trimmers/clipper. Worker should be trained about trimming process & its advantages.	Production Dept.	2/3/2023	On End line
6	Poor machine maintenance	It causes variation in process which results in poor quality, products defects, more energy consumption, and increased production cost	Trainings maintenance schedules should be provided & Autonomous maintenance technique should be implemented with the help of which employees will become expert in maintenance.	Floor Mechanic	14/3/2023	Production floor
7	Dull sewing machine wipers	It impact the quality of sewing process and results in thread build up & stitching defects.	Educating the workers to check, clean, adjust, & lubricate the wipers on daily basis. And report if wipers need to be replaced before starting production	Quality Control Dept.	8/3/2023	Production floor
8	Lack of new thread cutters	It may disturb the overall production process by producing defects. Thus, effecting product quality & increasing rework percentage.	Provide the thread cutters to the workstations where they are required. Check the availability and sharpness of thread cutters during thread cutting process.	Floor Mechanic	2/3/2023	Cutters should be provided on End line
9	Uneven light	Major quality defects may arise due to uneven light during production.	Identify the areas where light is uneven, especially workstations, inspection zones, and production line. An audit should be conducted in order to check the intensity and distribution of light wherever required.	Electrical Dept.	8/3/2023	On End line, because majority of the defects are not visible due to un even light.
10	Dust & contaminants	It interferes with cutting mechanism & hinder the cutting mechanism which results in incomplete thread cuts. Moreover, it causes the cutting blades to become dull with the passage of time which results in uncut threads.	The workers should be trained on 5S, to clean the sewing machines, work stations, & tools regularly, for which they should be provided proper such as compressed air or lint brushes to clean effectively.	IE Dept.	2/3/2023	Production floor

Once, the defects are controlled and sigma level is improved. The next stage is to compare the sigma levels before and after improvement. This comparison between sigma levels is presented with the help of histogram in **Error! Reference source not found..** Similarly, the defects percentages before and after improvements are compared in Figure **6.**

Table 1. Expert's profile.

Sr. No	Age	Experience	Position	Expertise
1	51	18	General Manager	Lean, Six Sigma, TPM
2	41	13	IE head	Technology & Innovation, Quality, Process optimization, DMAIC
3	46	16	Quality head	QC, QA, RCA, Quality Training & Education, Kaizen
4	49	19	Maintenance manager	Predictive, Preventive, & corrective maintenance
5	47	15	Production Manager	Process Optimization, Lean, Capacity planning, High & low volume production, OEE

This study can be concluded by stating the implementation of Lean Six Sigma methodology using DMAIC approach which starts by measure the current sigma level at Measure stage before making any improvements. In contrast, the sigma level can be measured again, after control stage in order to compare the sigma levels before & after improvements. On one hand, the methodology used in the study has helped to increase the sigma level from 3.9198 to 4.3546 while, on the other hand it dropped down the defect rate from 11.85% to 3.16%. This study also figured out that the major defect was uncut thread which was major source of thread wastage and overall production cost. The factors involved in this defect included usage of fabric cutters for thread cutting, improper finishing, workers negligence at work, carelessness of quality inspectors, poor machine maintenance, lack of thread cutters, uneven lighting, and dust & contaminants in production area.

The improvements that have been made include:

Installation of auto cutters on machines (Lock-Stich & Over-Lock), training & education of workers about procedure and techniques, procedures, & standards, implementation of quality checks, random inspections, scheduling maintenance once or twice a month, providing Work Instruction documents & warning signs on production floor, conducting audit to check the intensity and distribution of light wherever required, training operators about 5S and autonomous maintenance. Such improvements reduced 30% and 36% of thread wastage on Lock-Stitch machine and Over-Lock machine respectively, which saved overall cost of 129636 Rs. per month and reduced rework percentage, indirectly. The methodology developed in this research can be implemented in any textile industry in order to minimize waste (thread wastage especially) and process variation so that productivity will improve.

Conflicts of Interest

The authors declare no conflict of interest.

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